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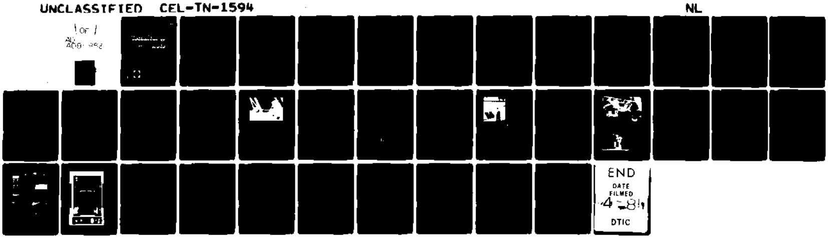

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Nondestructive test equipment for inspecting steel wire ropes was evaluated in laboratory and field tests. Individual AC/DC units and a unitized AC/DC unit were tested on wire rope to detect broken wires and loss of metallic area from wear and corrosion. The unitized AC/DC units used Hall effect sensors to pick up the defects as opposed to sensor coils used in the individual AC/DC units. The Hall effect sensors enabled less equipment to be used to conduct a complete inspection and also permitted the wire rope to be inspected at speeds

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CONTENTS

INTRODUCTION

Wire rope inspection is a problem to the Navy. At present only the outside surface of wire ropes can be inspected for broken wires, wear, and corrosion. Typically, an inspector uses a rag held around a moving wire rope as an aid in finding broken wires (Figure 1). Caliper measurements of the outside diameter of the wire rope give data on wear, and rust stains indicate corrosion. However, inspection cannot be complete without knowledge of the condition of the interior of the rope. Therefore, wire rope replacement criteria are based on conservative standards, because the alternative is risk of injury or loss of life from a rope failure.

Nondestructive test (NDT) devices have the capability to detect broken wires, wear, and corrosion throughout the entire cross section of a metallic wire rope. This inspection technique is an order of magnitude superior to the present visual method. Because the condition of the rope is known with confidence, accidents could be reduced and replacement criteria improved.

The Office of Safety and Health Administration (OSHA) requires that wire ropes be inspected periodically (frequency of inspection depends on the application.) The Department of Defense follows OSHA guidelines, and many man-hours are used for wire rope inspections. Potential users of NDT inspection equipment within the Department of Defense are numerous. The following applications are indicative of potential users:

- Crane wire ropes
- Personnel elevator wire ropes
- Ship cargo elevator wire ropes
- Bridge cables
- Mooring lines
- Underway replenishment cables for ships
- Catapults and arresting cables on aircraft carriers
- Undersea cable arrays
- Tether lines for diving bells
- Guy lines for transmission and receiving antenna towers
- Tramway wire ropes

To expand on one application, that of cranes, the Long Beach Naval Shipyard has about 430 cranes, both large and small, that require inspection. This shipyard is only one of eight Navy yards. The inspectors have the authority to "red tag" any wire rope that they deem unsafe and, thus, prevent the use of the crane until the rope is replaced. NDT equipment would greatly help the inspector in making decisions on whether a wire rope is safe by supplying technical data on the condition of the rope. Also, because some conservativism can be replaced by knowledge, it is likely that wire ropes will remain in service for longer periods of time.

This report on evaluating nondestructive test equipment for wire rope was sponsored by the Naval Facilities Engineering Command under the Specialized Inspection Systems (SPINS) Project.

BACKGROUND

NDT equipment for inspection of wire rope has been used for over 25 yr by the mining industry in many countries.* The United States has not participated in the mining industry's development of NDT inspection equipment.

Two basic types of equipment have been developed, which will be jointly called "individual AC/DC units." The AC unit uses alternating current to produce an electromagnetic field to detect loss of metallic area in the wire rope. The DC unit uses permanent magnets (analogous to a steady direct current) to detect broken wires. Typically, either AC or DC equipment is used in an inspection, seldom both. If DC is used, the wire rope needs to be demagnetized before AC can be used. The degaussing process is slow.

Recently a Canadian firm** developed a "unitized AC/DC system." This equipment can perform the functions of the individual AC/DC units during one pass of the wire rope through a sensor head. The equipment also has the feature of inspecting wire rope traveling at speeds from extremely slow to fast (0 - 500 fpm), whereas the individual DC unit can only function at rope speeds ranging from 50 to 500 fpm. The slow speeds are invaluable when trying to locate broken wires for detailed visual inspection.

During 1979, the Civil Engineering Laboratory worked with an individual DC unit. A U.S. firm,*** which manufactured NDT equipment for quality control inspection of small diameter pipe, was contracted by CEL to adapt their equipment to 1-1/8-inch-diameter wire rope. The equipment used the same engineering principles of operation as the individual DC unit for wire ropes. The equipment was tested, and the results were reported in Reference 1.****

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*Partial list of manufacturers of NDT equipment for wire rope:
- Kundig AG, Switzerland
- Academy of Mining and Metallurgy, Poland
- Rotesco Ltd., Canada
- ACMI, Belgium
- Mitsui Miike, Japan
- Plessey-Slack, South Africa

**Noranda Research Centre, Quebec, Canada. [Manufacturer is Heath and Sherwood (1964) Limited, Ontario, Canada.]

***Magnetic Analysis Corporation, New York.

****Civil Engineering Laboratory. Technical Memorandum M-40-80-2-R: Report on NDT inspection of wire rope using electromagnetic equipment, by Earl F. Buck, Phillip C. Zubiate, and Harvey H. Haynes. Port Hueneme, Calif., Mar 1980.

During the same time period, Noranda began to market a unitized AC/DC unit, called a Magnograph. CEL observed a demonstration test and subsequently procured a Magnograph unit for test and evaluation work.

During one sequence of laboratory and field tests, individual AC/DC units were tested side-by-side with the Magnograph. The Mine Safety and Health Administration, who owned and operated the individual AC/DC units for about 1 year, came to CEL with its equipment and an experienced operator for the comparison tests. The results of the comparison are presented herein along with other results and information on the Magnograph unit.

THEORY

The principles of operation for the individual AC/DC units and the unitized AC/DC unit will be discussed in the following sections.

Individual AC/DC Units

DC Unit: In the DC unit, strong permanent magnets are placed around a section of wire rope so that the rope becomes saturated with magnetic lines of flux (Figure 2). Lines of flux can be observed by iron filings sprinkled on top of a piece of paper having magnets underneath (Figure 3). The flux appears to "flow" from the north to south pole; however, the lines are stationary. The lines of flux are also distinct because of the existence of both attractive and repulsive forces. Saturation means that if stronger magnets were used, the number of lines of flux for a given cross section (flux density) would remain essentially unchanged.

If a broken wire were present in a saturated section of rope, then a north and south pole would be formed and the lines of flux would "jump" the gap (Figure 4). It is these lines of flux, called flux leakage, that can be detected to indicate a broken wire. Pitting from corrosion and localized wear will also interrupt the saturated lines of flux and cause flux leakage.

A classic physics experiment is to demonstrate that a magnetic field can produce an induced voltage in a conductor that is passed through the magnetic field. The conductor, passing at right angles through the lines of flux, must have a minimum travel speed through the flux field in order for the voltage to be large enough to measure (Figure 5).

Flux leakage in the wire rope is detected by using this phenomenon. However, in this case, the conductor is a search coil that is held stationary while the magnetic field is moving. In the inspection equipment, search coils are placed around the saturated wire rope between the poles of the permanent magnet. The rope travels at some minimum speed; thus, any flux leakage will also be moving and will pass through the search coils (Figure 6). When this occurs, an induced voltage is generated in the search coils, and, by proper amplification and conditioning of the signals, the broken wire is detected.

For the DC unit, there must be relative motion between the sensor coil and the wire rope. This means that the rope must travel through the sensor head or, for a stationary rope, the sensor head must travel along the wire rope. A minimum velocity of about 50 fpm is required.

Below this speed the induced voltage in the sensor coil is too small to detect broken wires. The velocity must also remain constant for signal strength to be consistent; however, to account for changes in velocity, the DC unit is built with a tachometer coupled to an amplifier so that signal strength can be amplified for changes in velocity.

Two search coils are usually built into the sensor head, as shown in Figure 6, to allow the head to clamp around the rope. Data output can take several forms because signals from two search coils are available. Usually two output traces are shown so signals from coil A and B can be displayed as a combination of A, B, A + B, $(A + B)^2$ or AB. Typically the data is displayed as A + B on one trace and $(A + B)^2$ on the second trace.

AC Unit: A relatively weak alternating magnetic field is produced by electromagnets in an AC unit sensor head. These magnets function as the primary coil of a transformer (Figure 7). The wire rope serves the purpose of the ferromagnetic core of a transformer. A secondary coil in the middle of the sensor head produces an output voltage that is proportional to the magnetic flux "flowing" through the wire rope. Variations in the cross-sectional area of the wire rope influences the strength of the magnetic flux field and, thus, the strength of the output voltage. Hence, loss of metallic area can be measured by the output voltage.

The sensor coil measures the metallic volume over a 2- to 3-inch length of wire rope. Wear and corrosion can produce a significant volume change within the finite length, but a single broken wire with a small gap between the ends reduces the volume insignificantly. If many breaks occur within the finite length or a wire is missing, then a defect signal may be recorded.

In the AC unit, the magnetic flux field always varies with time because of the alternating field. Hence, a voltage is produced in the sensor coil whether or not the rope moves.

Because of the alternating magnetic field, small electric currents are induced that circulate around the rope axis within and between the wires. These eddy currents also alternate and produce their own magnetic fields which tend to oppose that from the primary field. This opposition produces a phase shift between the peaking of the magnetizing current and that of the sensor coil voltage. Built-in circuits in the instrumentation utilize the phase shift to produce a second data trace. The first data trace, called X, is essentially proportional to the axial component of the flux field in the rope, and therefore, measures loss of metallic area. The second trace, called R, is proportional to the magnitude of the eddy currents and reflects conditions within the rope that cause changes in the eddy currents. Corrosion products or lay tightening or loosening will affect the passage of eddy currents. Thus, by comparing the X and R traces, wear and corrosion can usually be differentiated.

Unitized AC/DC Unit

The unitized AC/DC unit uses a sensor head having strong permanent magnets to saturate the wire rope with magnetic flux. This is similar to the individual DC unit; however, the means of sensing the faults in the rope is different. Hall effect sensors are used to detect faults.

Hall effect sensors are solid state devices which can detect and accurately measure magnetic fields. Figure 8 shows a sketch of a sensor. Electrical wires are bonded to all four sides of a semiconductor chip. A constant current is passed between two opposing edges. The other two edges develop a potential difference when the semiconductor chip is placed in a magnetic field. The potential difference developed by the sensor is directly related to the strength of the flux field. Static magnetic fields can be measured; this is a feature not available in the individual AC/DC units. This means that ropes traveling at extremely slow speeds can be inspected, which is desirable when trying to pinpoint a fault location.

Figure 9 shows the placement of Hall effect sensors in the Magnograph sensor head which clamps around a wire rope. The Hall effect sensors located between the poles of the magnets pick up flux leakage, which indicates broken wires or other local faults (or LF). The Hall effect sensors at the poles of the magnets measure the quantity of flux "flowing" into the wire rope. When the cross-sectional area of steel changes, so does the flux "flowing" into the rope; thus, loss of metallic area (or LMA) is measured.

TESTS

Laboratory Test

A laboratory test was conducted on a new steel wire rope, 6 x 19 independent wire rope core, 1-1/8-inch diameter, extra improved plow steel, right lay hoisting rope, which contained man-made faults. Individual AC/DC units were tested along with the Magnograph unit (Figure 10).

Data from the tests are shown in Figures 11 through 13. The numbers on the traces identify the various faults, which are explained as:

1. "Broken" outside wire: A piece of wire 2 inches long (cut from the end of the rope) was taped into the groove between two strands.
2. Corrosion: A section of wire rope about 18 inches long was soaked in nitric acid for 35 minutes to produce mild corrosion of the steel.
3. Broken outside wire: A single wire on the outside surface was cut with a chisel.
4. Wear: A hand-held power grinder was used to wear away steel.
5. "Broken" inside wire: A piece of wire 1 inch long (cut from the end of the rope) was inserted in the middle of the wire rope.

Figure 11 shows the data from the individual DC unit. The top trace presents the data for sensor coils A and B as the square of the sum $(A + B)^2$ and the bottom trace as the sum A + B. The broken wires, numbers 1, 3, and 5, were detected well. Note that the direction of the signal spike is in the opposite direction for the added wires, numbers 1 and 5, than that for the cut wire, number 3.

Corrosion pitting and local, uneven wear cause flux leakage; these faults (numbers 2 and 4) were detected. Fault number 2 appears to be a larger wire break (or the sum of several wire breaks) than that of faults 1 and 3; however, corrosion can usually be distinguished from broken wires because of the length of rope over which corrosion occurs. This test rope had an unrealistically short length of rope with corrosion.

Figure 12 shows the data from the individual AC unit. Little data could be obtained from the AC unit because the equipment was designed for field test situations. The full-scale LMA trace was factory set at 25%; hence, with the pen set in the middle of the trace a ±12.5% loss of metallic area could be recorded. Faults 2 and 4 had LMA readings around 0.5% which were too small for the AC equipment to record. The chart paper speed was also factory set at one speed, 2 mm/sec, which is appropriate for long lengths of rope (thousands of feet) but not the short test length of wire rope. The bottom R trace, which gives a relative indication of magnetic permeability, did not produce meaningful data during the laboratory test.

Figure 13 shows the data from the Magnograph unit. The top trace is LMA data and bottom trace LF data. The LMA full-scale setting was set at 5%; hence, faults 2 and 4 were both recorded as having an LMA of 0.5%. The LF trace was essentially identical to that of Figure 11. Interpretation of data is made easier by having the LMA and LF traces together. The corrosion faults, 2 and 4, can be distinguished from the broken wire faults of 1, 3 and 5.

Field Tests

Manitowoc Crane: The load line to a Manitowoc crane, series 4100, having a lift capacity of 300 tons, was inspected using individual AC/DC units and the Magnograph unit. The wire rope was a 6 x 19 independent wire rope core, 1-1/8-inch diameter, improved plow steel, right lay hoisting rope. Approximately 600 ft of wire rope was inspected.

The individual DC unit produced a trace of local faults that showed three definite defects and two probable defects. The signal size for the probable defects was larger than background noise but not as large as the other defect signals. No attempt was made to try to locate the defects in the wire rope because: (a) there was no means to pinpoint the defects, (b) a length of rope from 3 to 5 yards long would have had to be cleaned and searched, and (c) inspection by the Magnograph was to follow where the defects could be pinpointed.

Prior to using the individual AC unit, the wire rope was degaussed. The process was not only slow but also unsafe. The design of the degaussing equipment required that the unit be held by hand as the rope moved through at a maximum speed of 50 fpm (Figure 14). The close proximity to a moving wire rope while the inspector's body became fatigued holding the degaussing box was unsafe. In addition, the copper strap clamp over the wire rope became hot from resistance to current flow.

In some situations, the AC unit could be used before the DC unit so that degaussing may not be necessary. However, any stray magnetic flux picked up by sections of a wire rope produce erroneous readings on the AC trace; those sections of wire rope, and only those sections, need to be degaussed. If at any time previously (meaning months and years), the wire rope was inspected with a DC unit, then the wire rope needs to be degaussed.

The AC unit was set up on the wire rope, but an inspection was not completed. Data were unusable because clean 115 VAC line power was not available. A generator source and available shore power source were tried; however, time was not sufficient to try other sources. Electrical equipment problems were encountered.

The Magnograph unit was the equipment tested last. Degaussing was not necessary prior to using the Magnograph unit. The local fault trace showed three distinct defects while the loss of metallic area trace showed negligible wear or corrosion. After locating the defects, they were identified as: (a) a 1-inch-long piece of wire that had been completely sheared off, (b) peening from the cable hitting the side of the drum, and (c) a nick on an outside wire.

The defects coincided with those from the DC unit in signal size and relative location along the length of the wire rope. The Magnograph unit showed absolutely no indication of the two probable faults shown on the DC trace. Standard procedure calls for a wire rope to run through the sensor head twice so that signal peaks from stray background noise can be eliminated as probable defect signals. Two runs were made with the DC unit and the probable defect signals appeared both times. Two runs were also made with the Magnograph unit and no indication of the questionable defects were found. It is the opinion of the authors that the probable defects did not exist. Subsequent testing indicated that the signal strength for the probable defects was too small to be faults.

Floating Crane: A floating crane, YD171, having a lift capacity of 350 tons, is stationed at the Long Beach Naval Shipyard (Figure 15). The crane was built in Germany in 1941 and brought to the United States after WW II. Since 1946, the records show that the main wire ropes have not been replaced.

The crane has a left and right main wire rope which service separate hooks of 175 tons lift capacity. Both of the wire ropes were scheduled for replacement by using "new" wire rope that came with the crane. The Civil Engineering Laboratory inspected the main wire ropes and the replacement wire ropes with the Magnograph equipment.

Both main wire ropes were 8 x 36 construction, 1-7/8 inches in diameter; however, the left main rope had a fiber core and the right main rope had an independent wire rope core. The replacement wire ropes were of the same size as the ropes in use and both had an independent wire rope core.

Each wire rope was 930 yards long. For the wire ropes on the crane, the middle 730 yards were inspected. At the drum end, a length of about 100 yards was wrapped on a drum, and at the boom end, about 100 yards was inaccessible for safe working conditions.

The results from the inspection found one broken wire in the right main wire rope and a loss of metallic area of about 1.5% from wear and corrosion in both main wire ropes. However, the left main wire rope, which had a fiber core, showed more evidence of corrosion pitting in the LF trace than the right main wire rope. In any event, 1.5% loss of metallic area was low (10% LMA is the level for wire rope replacement), so the wire ropes were in good condition.

The replacement wire ropes did not have any broken wires, but they did have a loss of metallic area on the order of 1.5%. Sections of wire rope showed corrosion pitting to be greater for the replacement rope than for the rope in use. This finding indicated that the maintenance of the wire rope on the crane must have been excellent over the years.

As an outcome of the nondestructive test, the wire rope on the floating crane was determined to be in a safe, usable condition and need not be replaced.

COMPARISON OF FEATURES

Table 1 is a summary of the instrumentation and operational features of the Magnograph unit and the individual AC/DC units. The Magnograph unit uses fewer components to conduct a test. Three pieces of equipment, the sensor head, electronics section, and recorder section, are required to obtain LF and LMA data. To obtain the same information, the individual AC/DC units requires five pieces: DC sensor head, DC electronics section, degausser unit, AC sensor head, and AC electronics section.

The Magnograph unit has two technical features that are superior to that of the individual AC/DC units. First, the LF and LMA data are displayed on the same brush chart recorder trace. This permits a more complete interpretation of the results. It is a definite aid to inexperienced personnel in determining what types of defects the data signals represent. Second, the sensor head picks up defect signals at slow wire rope speeds. This provides a means to quickly locate the defects for visual inspection.

SUMMARY

Laboratory and field tests were conducted on NDT equipment for wire rope. A unitized AC/DC unit was found to provide several important features that individual AC/DC units were technically unable to provide. Those features were:

(a) A range of operating speeds from 0 to 500 fpm for wire rope traveling through the sensor head. The extremely slow speeds are important for locating defects for visual inspection. An individual DC unit is limited to 50 to 500 fpm.

(b) Data displayed on a two-channel brush chart recorder that showed concurrently the local faults and the magnitude of loss of metallic area. Data interpretation is aided by these two important parameters being displayed together. Individual AC/DC units must measure local faults and loss of metallic area separately by using different equipment for each parameter.

The unitized AC/DC unit, developed by Noranda Research Centre and called the Magnograph unit, performed well in inspecting metallic wire ropes.

RECOMMENDATIONS

Based on the test and evaluation work reported herein, the unitized AC/DC unit has two important features over that of individual AC/DC units for Navy applications. Those features are listed in the summary section. It is recommended that the Navy procure unitized AC/DC equipment for meeting its needs in inspecting metallic wire rope.

In anticipation of Navy shipyards and other operational facilities providing their inspectors with NDT equipment, it is recommended that further tests be conducted using the Magnograph unit so that a compendium of defect signals can be published to assist inspectors in data interpretation. The operational limits of the equipment need further investigation, and this information also needs to be conveyed to inspectors by an operator's manual document.

Table 1. Comparison of Features Between Unitized and Individual Units

Item	Unitized AC/DC Unit (Magnograph)	Individual AC/DC Units	Comments
Instrumentation	One sensor head for detecting local faults (LF) and loss of metallic area (LMA).	One DC sensor head for detecting LF and a different AC sensor head for LMA. Degaussing required to demagnetize wire rope before using AC unit.	Magnograph requires only one set up on the wire rope to test for LF and LMA.
	One electronic section used to condition signals and to record data on cassette tape. A second recorder unit used to record data on a two-channel brush chart.	An electronic section required for each DC and AC unit.	AC/DC units require three setups for a complete test. A degaussing unit is needed between the DC and AC units.
	Total of three pieces.	Total of five pieces.	
Data Recording	Electronic section has FM cassette tape recorder. Recorder section has a Gould two-channel brush chart real time data display.	The DC and AC electronic sections contain Gould two-channel brush chart real time data display.	Data tape recording and playback capability of Magnograph is valuable for studying defect signals. Data on tape is good for record keeping and legal evidence.
Power Supply	Electronic section and Recorder section have built-in 6-hr capacity rechargeable batteries. Terminals available to use 12 VDC car battery and 115 VDC for charging or powering units.	DC and AC electronic sections both require "clean" 115 VAC, 60 Hz.	"Clean" line power (115 VAC) difficult to find under field conditions. AC/DC units require a car battery with converter if line power is not available.

continued

Table 1. Continued

Item	Unitized AC/DC Unit (Magnograph)	Individual AC/DC Units	Comments
Rope Speeds	Two speed settings are provided: a dynamic setting for wire rope speeds of 50-500 fpm, and a static setting for wire rope speeds of 0-50 fpm.	DC unit can operate at wire rope speeds of 50-500 fpm. AC unit can operate at wire rope speeds of 0-500 fpm.	Magnograph's static setting allows pinpoint location of LF defects for visual inspection (within 2 in.). DC unit can only locate defects within 3-5 yd.
Rope Sizes	Sensor head accomodates wire rope sizes of ½- to 2½-in. diam by providing four interchangeable sleeves. Sensor head weighs 105 lb. Manufacturer is building a smaller sensor head for wire rope sizes of ½- to 1½-in. diam. Three interchangeable sleeves will be provided. This sensor head weighs 65 lb.	DC sensor heads: (a) Small head for wire ropes ¼- to 1-in. diam, weight 40 lb. (b) Medium head for wire ropes ½- to 1-3/4-in. diam, weight 75 lb. (c) Large head for wire ropes 3/4- to 2-1/4-in. diam, weight 105 lb. AC sensor head accomodates wire 3/4- to 2-1/4-in. diam, weight 30 lb.	
Data Display	LF signals easily distinguished from background noise. LMA signals can be shown at full-scale values of 5, 10 and 25% loss of metallic area for cross section of wire rope.	LF signals easily distinguished from background noise. LMA signals shown at full-scale value of 25%.	

continued

Table 1. Continued

Item	Unitized AC/DC Unit (Magnograph)	Individual AC/DC Units	Comments
	Chart paper speed controlled two ways: (a) Time drive, setting of 1, 2, 5, 10, 25, and 50 mm/sec. (b) Proportional drive chart length represents wire rope length with ratios of 1, 2, 5, and 10 mm/yd of wire rope.	Chart speed controlled by time drive: For DC unit, chart speeds of 1, 2, 5, 10, 25, and 50 mm/sec are available. For AC unit, the chart speed is set at 2 mm/sec.	Proportional drive on Magnograph is useful when rope speeds vary during test. The chart is proportional to the wire rope length. Future charts can be made the same length for data comparison
	Length of wire rope tested is shown in two ways: (a) Digital display on electronics section (yards or meters) (b) Brush chart recorder has two markers, one marks off yards (meters) and the other marks off 50- and 100-yd (meter) distances. (c) Direction of rope travel is shown by yard marker.	Length of wire tope tested is shown in two ways: (a) A mechanical counter records rope length. The counter does not subtract if the wire rope changes direction. (b) A marker marks 100-ft distances on brush chart.	
	Speed of the wire rope is digitally displayed on the electronics section and recorded on tape.	Speed of wire rope is shown on a mechanical gauge on the electronics section.	

Figure 1. Conventional method for inspector to locate broken wires on outside of wire rope.

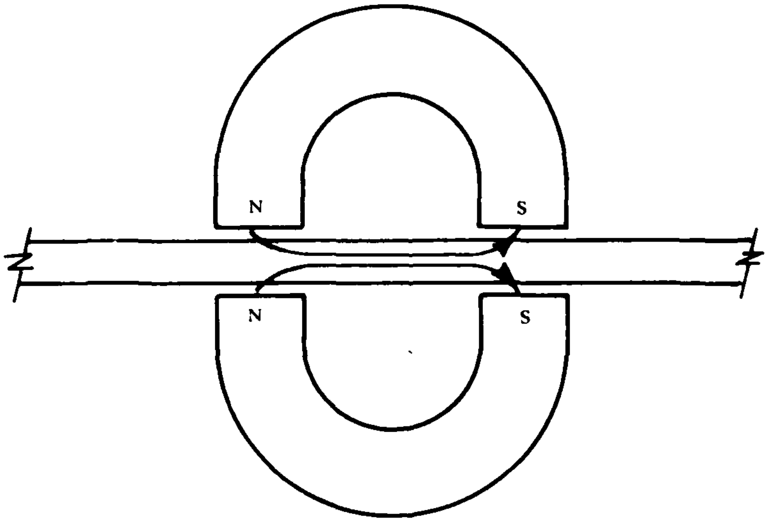

Figure 2. Saturation of wire rope with lines of flux.

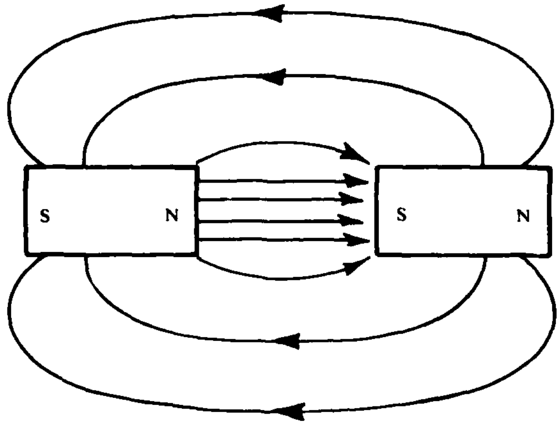

Figure 3. Lines of flux.

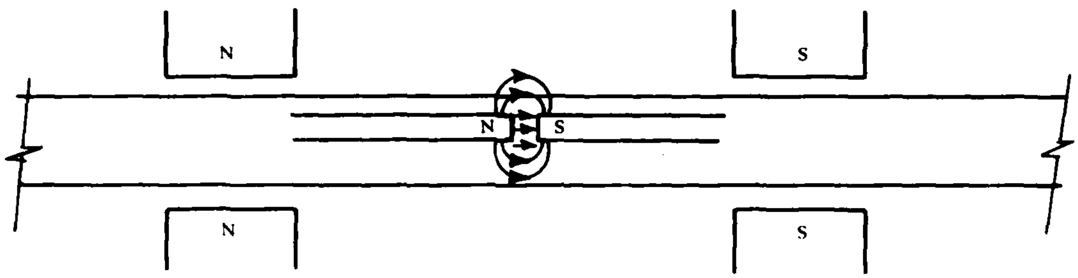

Figure 4. Flux leakage at location of broken wire.

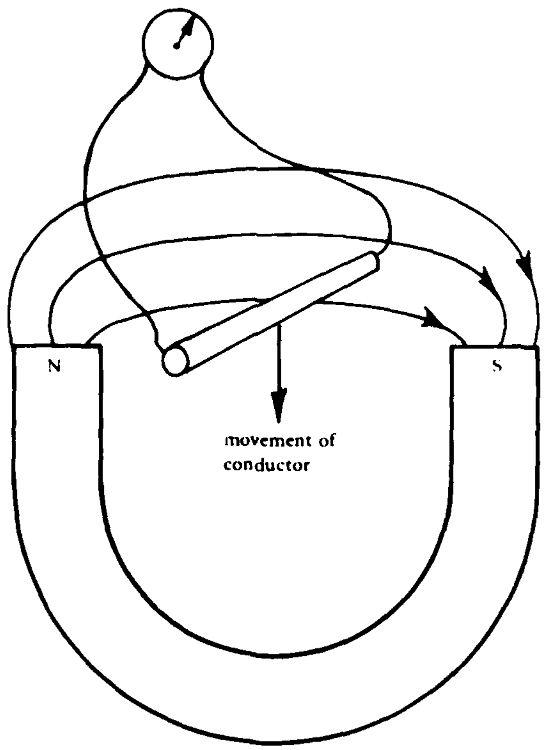

Figure 5. A current is created in a conductor moving through lines of flux.

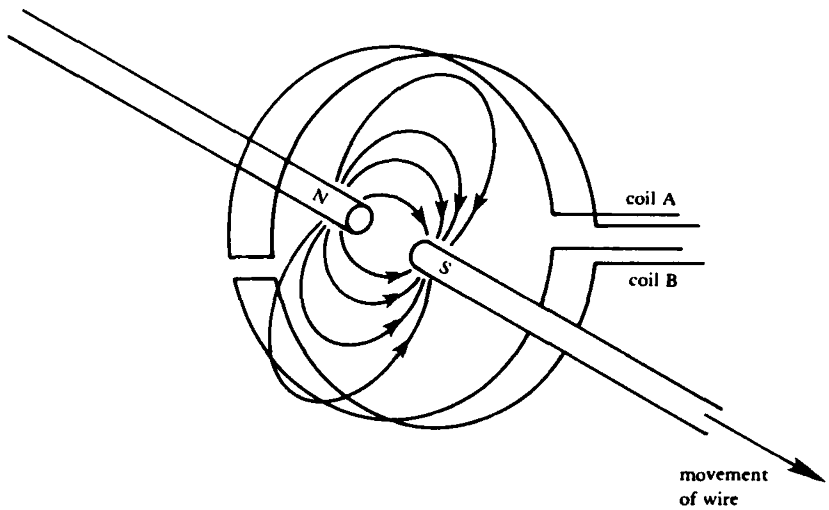

Figure 6. Search coils pick up radial component of flux leakage.

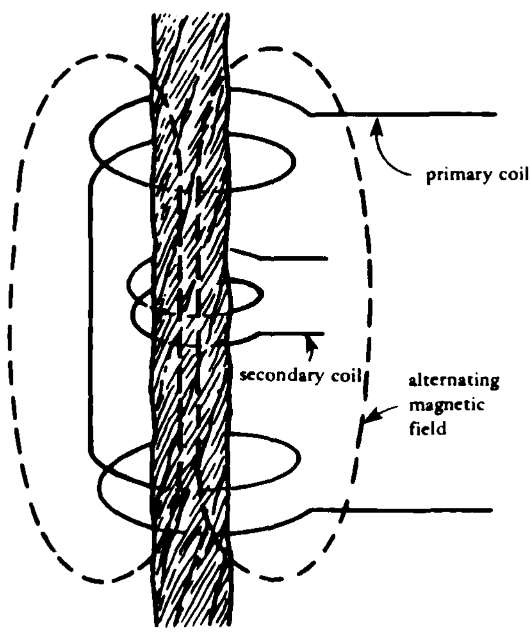

Figure 7. The basic principle of the AC method.

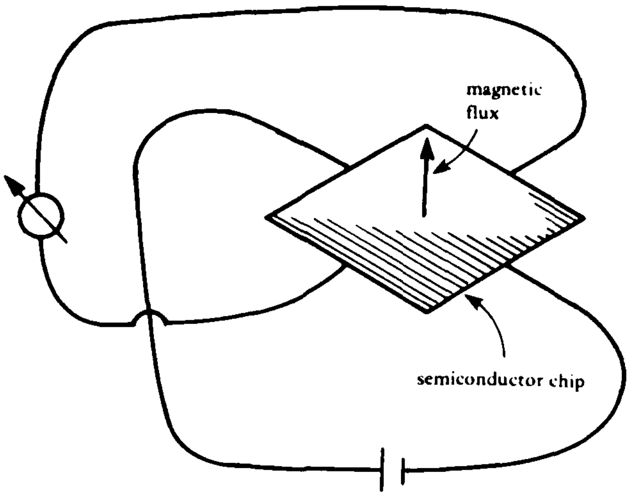

Figure 8. Sketch of a Hall effect sensor.

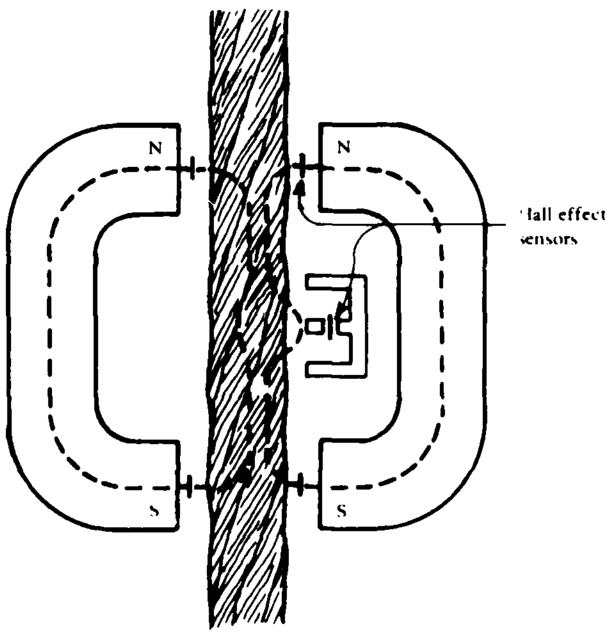

Figure 9. Hall effect sensor placement for the Magnograph.

Figure 10. Setup of Magnograph nondestructive test equipment for a test on a crane wire rope. Electronic and recorder sections are in foreground and sensor head in background.

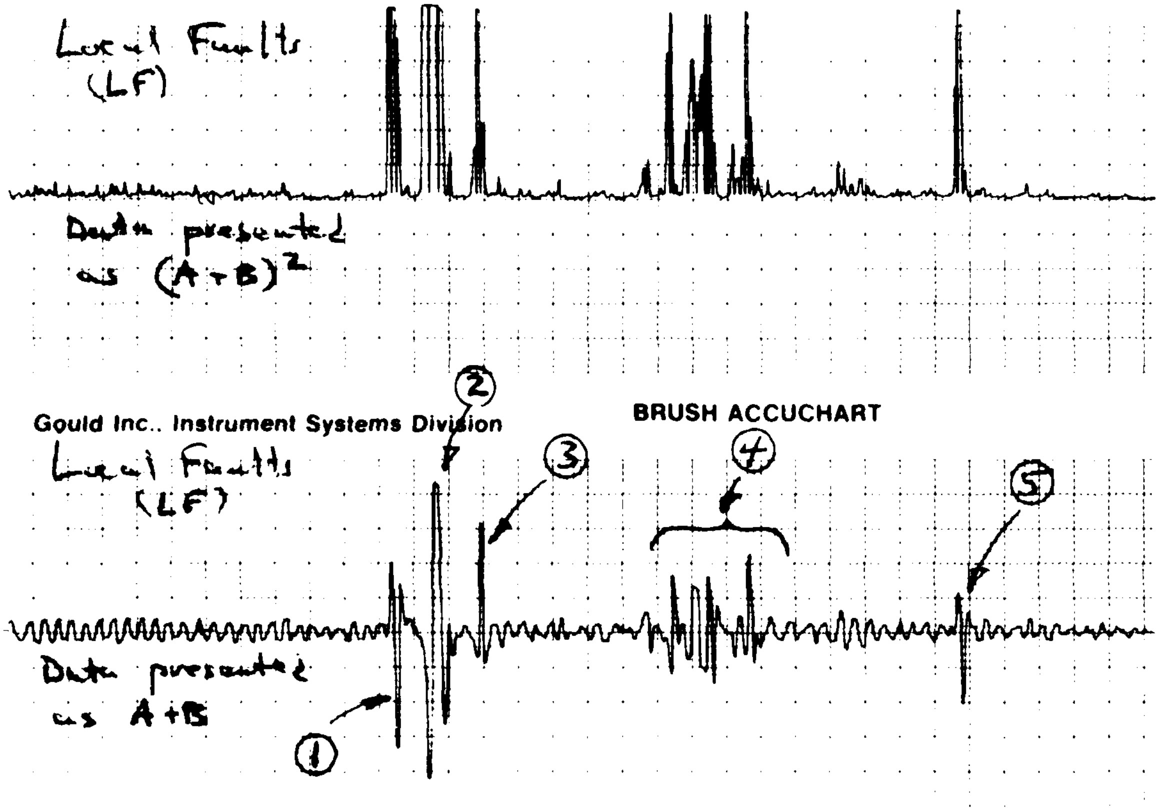

Figure 11. Data from laboratory test on an individual DC unit.

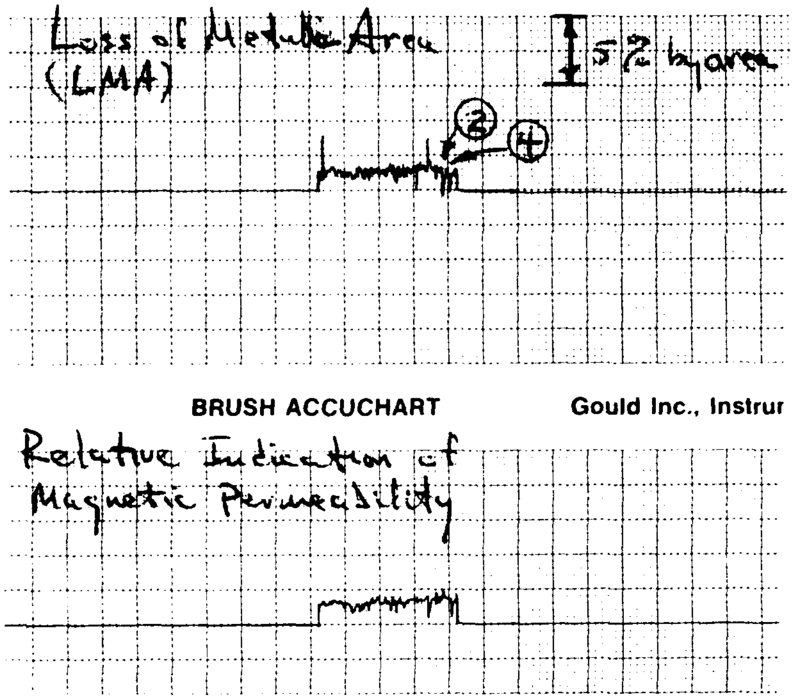

Figure 12. Data from Laboratory test on an individual AC unit.

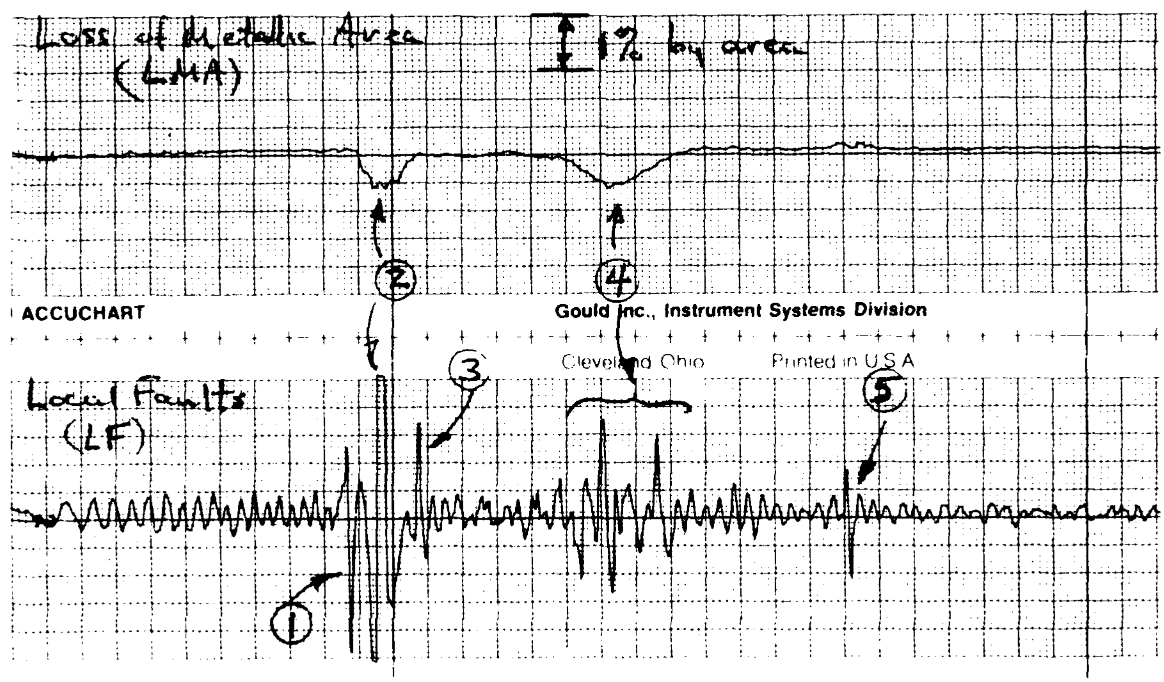

Figure 13. Data from laboratory test on the Magnograph unit.

Figure 14. Degaussing wire rope between tests using individual DC and AC units.

Figure 15. Floating crane at Long Beach Naval Shipyard.

Appendix

DESCRIPTION OF NORANDA'S MAGNOGRAPH EQUIPMENT

FRONT PANEL CONTROLS - ELECTRONICS (Figures A-1 and A-2)

1. Power ON/OFF Switch (should be OFF during battery charging)

2. Powerline/Mains connection

3. Sensor Head Connection (NOT necessary during playback mode)

4. Chart Recorder Connection

5. Battery Check Switch:

   When depressed, battery state is indicated on LMA analog meter (6).

6. LMA Analog Meter:

   Displays same signal as the chart recorder LMA channel during record and playback. May also be used for zero adjustment.

7. Metric/English Switch:

   Selects either SI or Imperial Units as the basis of all measurements.

8. Rope Direction Switch:

   Changes counting direction of Measured Length Up/Down Counter.

9. Loss of Metallic Area (LMA) Gain Potentiometer:

   Used to set the gain of the LMA Channel according to the size and type of rope being tested.

10. LMA Zero Potentiometer:

    Used to zero the LMA Signal before commencing a test.

11. Offset % LMA Switch:

    Used during a test (if necessary) to move the LMA zero by a fixed percentage.

12. Local Fault (LF) Gain Potentiometer:

Used to set the gain of the LF Channel according to the size and type of rope being tested.

13. LF Zero Potentiometer:

Used to zero the LF signal before commencing a test.

14. Compression Band Division Switch:

Used to reduce the rope noise component of the LF signal.

15. LF Analog Meter:

Displays similar signals to the Chart Recorder LF channel, during record and playback. Also may be used for zero adjustment.

16. Static/Dynamic Switch:

Normally used in Dynamic mode for rope speeds 50 to 500 fpm. Below 50 fpm, static mode should be selected.

17. Measured Length Counter (and Reset):

Displays distance traveled along a rope. Counts both Up and Down. Can be Reset using the push button.

18. Wire Rope Speed:

Displays the rate of movement of the rope through the Sensor Head.

19. Tape Counter (and Reset):

Indicates position on the tape cassette.

20. Record/Play Switch:

Selects either Record or Playback mode for both the cassette recorder and the internal electronics.

21. Cassette Tape Recorder with Standard Controls:

Record Button
Tape Run
Rewind
Stop
Fast Forward

22. External Battery Connections

23. External Battery Power Indicator (illuminates if connection is correctly made)

FRONT PANEL CONTROLS - CHART RECORDER (Figure A-3)

1. Power Line/Mains Connection

2. External Battery Power Indicator Light (illuminates if connection is correctly made)

3. External Battery Connections

4. LF (Local Fault) Channel Input (for test purposes only)

5. LF Channel Pen Position

6. LF Sensitivity Variable Potentiometer:

   Should be fully clockwise

7. LF Sensitivity Switch:

   Should be set at 10 mV for Magnograph recordings

8. LF Channel Input Shorting Switch

9. LMA Channel Input Shorting Switch

10. Chart Speed Selectors:

    Used when TIME BASE mode is selected

11. Battery State Indicators:

    Battery needs recharging when indicator enters the red area

12. LMA (Loss of Metallic Area) Sensitivity Switch

13. LMA Sensitivity Potentiometer:

    Should be fully clockwise

14. LMA Channel Pen Position

15. LMA Channel Input (for test purposes only)

16. Electronics Section Connector

17. Proportional Drive Selector:

    Selects chart recorder timebase or proportional drive

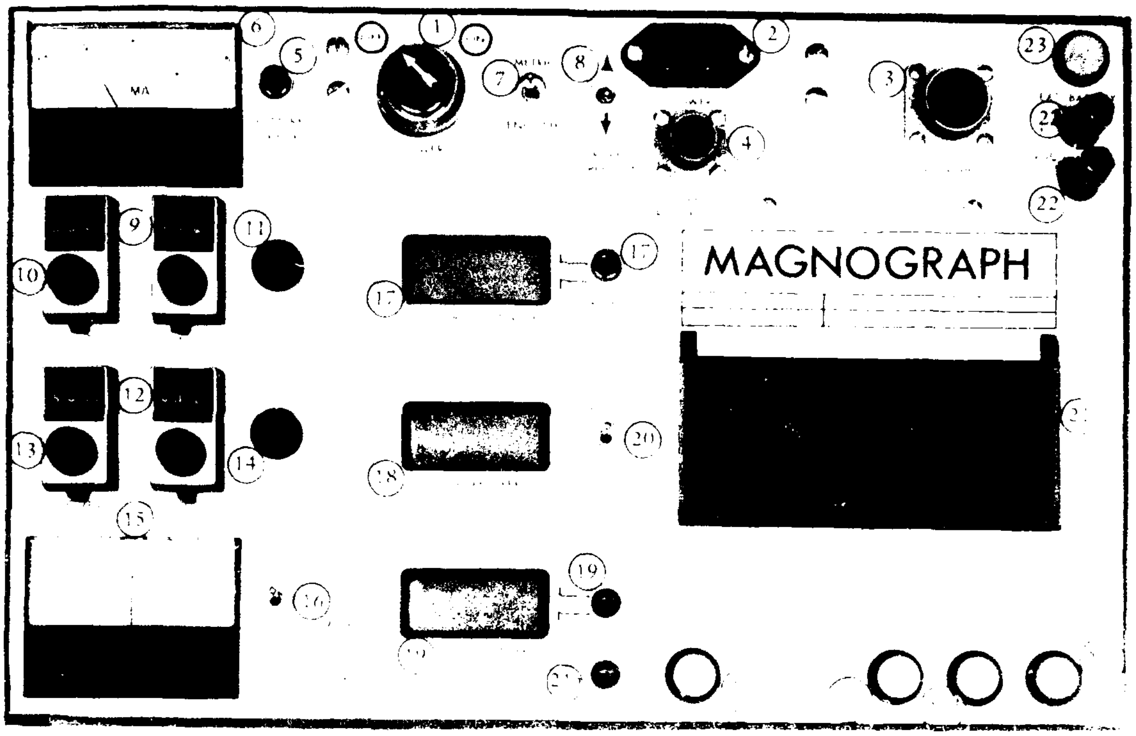

Figure A-1. Front panel controls, electronics section.

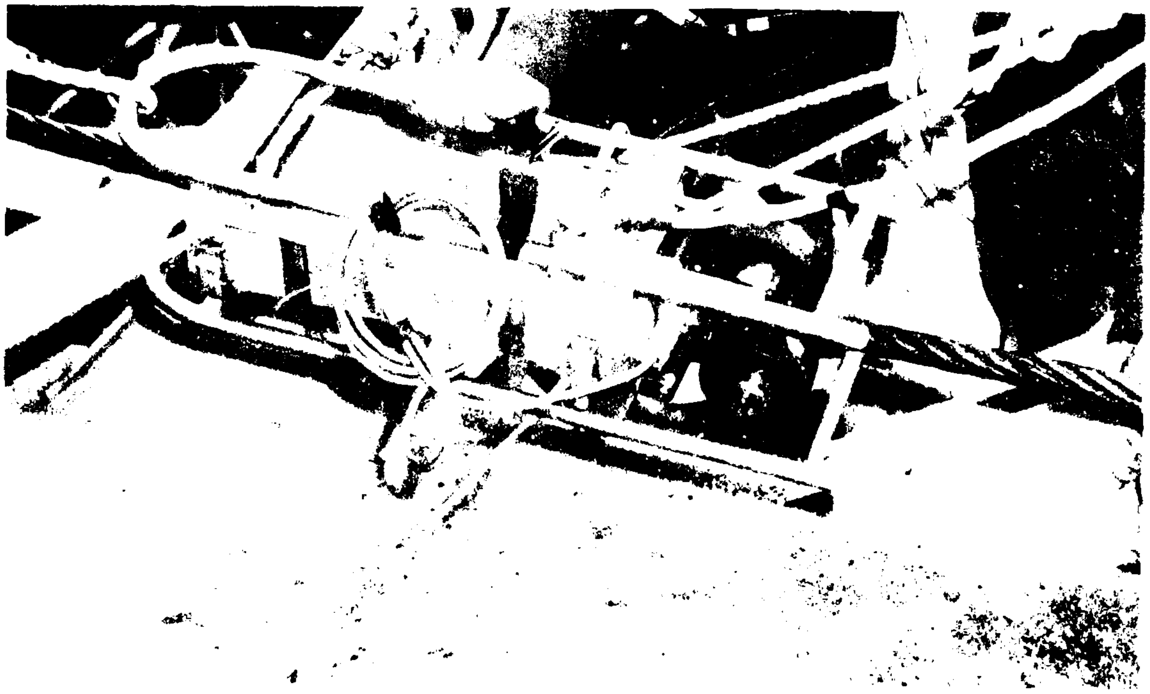

Figure A-2. View of Magnograph sensor head.

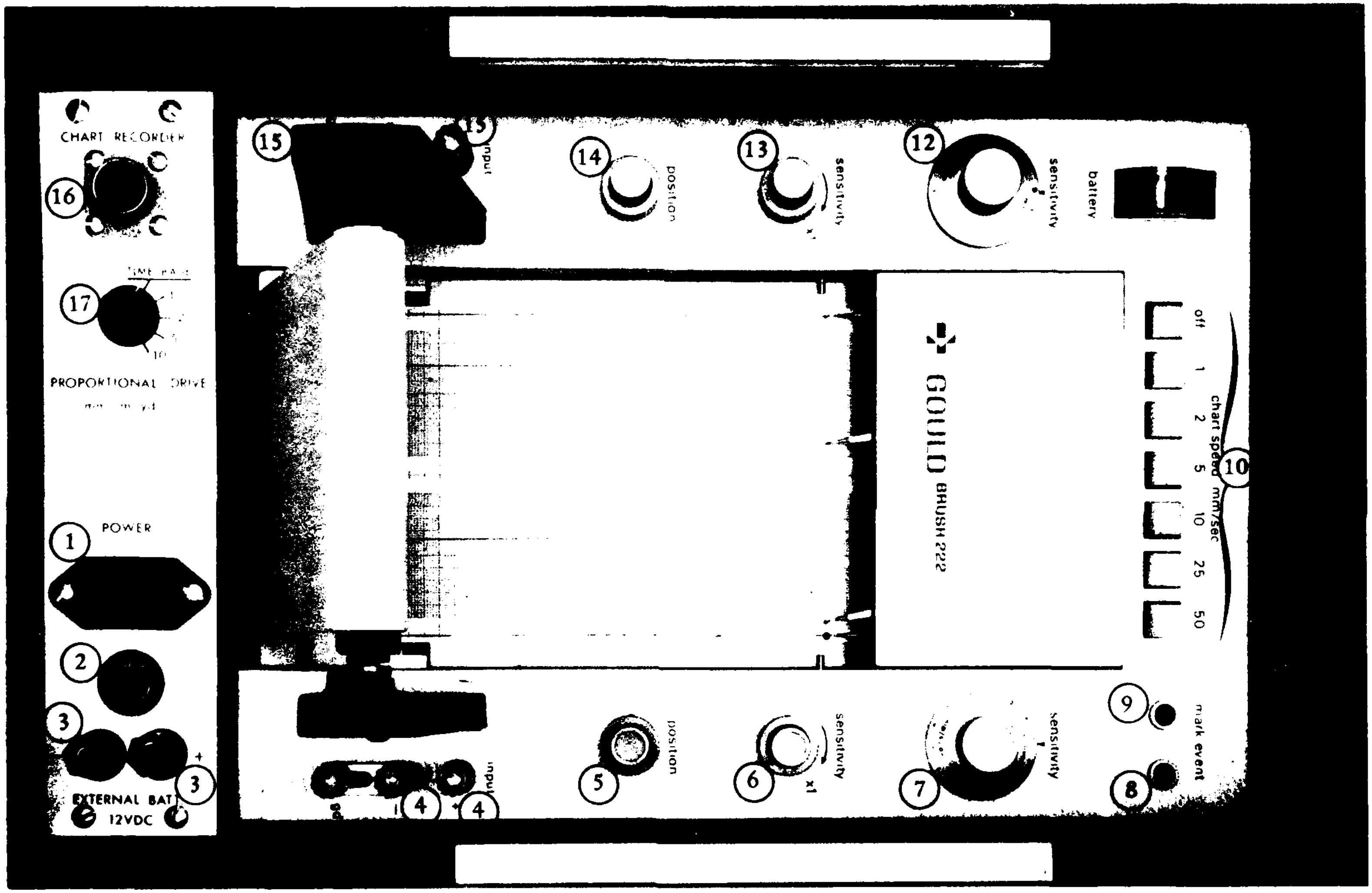

Figure A-3. Front panel controls, chart recorder.

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